REPORT on
Nutrient Removal at the
Sunderland Wastewater Treatment Plant

October 2014

Background

Concerns about nitrogen levels in Long Island Sound and elsewhere across New England are affecting discharges from facilities such as the Sunderland wastewater treatment plant. Facilities are being asked to optimize nutrient removal. Permit limits will surely follow.

Optimization work performed at the municipal wastewater treatment facilities serving Amherst, Westfield, Montague, and Palmer has resulting in impressive reductions in the discharge nitrogen and phosphorus at reduced cost. The efforts have not only eliminated the need for tens of millions of dollars of facility upgrades, the facilities listed have reduced the cost of wastewater treatment by nearly $1,000,000 annually.

Beginning mid-2014, Warner Brothers' staff began experimenting with process changes. The mixed liquor concentration with successful results: sludge production has been reduced by approximately 50% from 8-10 loads per month to 3-4 loads per month; providing ongoing annual savings. Aeration equipment was cycled on and off in an effort to improve total-nitrogen removal with mixed success.

In light of the promising results, Warner Brothers, the operator of the Sunderland wastewater treatment facility recommended the employment of The Water Planet Company to work with Warner Brothers staff to optimize nutrient removal.

Project Overview

Three visits to the Sunderland wastewater treatment plant were made (8/6/14, 9/16/14, and 10/15/14). Between visits, plant operations were discussed via email and telephone. During the first visit, changes were made to the aeration system: the air on and air off cycle times were extended such that the air was on for 3 hours and off for 1 hour and later to the 4 hours on and 45 minutes off. New laboratory equipment costing approximately $750 was purchased before the second visit in order to (a) more accurately measure ammonia-nitrogen, nitrate-nitrogen, and nitrite-nitrogen and (b) provide data on ORP, oxidation reduction potential.

Data were reviewed during the subsequent visits and process adjustments were made in an effort to optimize nitrogen removal. The project focus was entirely nitrogen removal; no efforts were made to optimize phosphorus removal (more on this at the conclusion of the report).

Results

Optimization efforts provided immediate, positive results. Ammonia-nitrogen was reduced by 80% from 10.4 mg/L to 2.1 mg/L and total-nitrogen was reduced by 50% from 15.0 mg/L to 7.3 mg/L*. However, as shown in the table that follows, nitrogen values spiked after Labor Day, returning to nearly the same levels as before the optimization effort.

Table 1: Sunderland In-house* Nitrogen Testing (2014)

	Ammonia*	total-N*
July 1 - August 5	10.4	15.0
August 6 - August 31	2.1	7.3
September 1 - October 15	8.2	13.7

Observations

Nitrogen Removal. By cycling existing aeration equipment, the Sunderland wastewater treatment facility should be capable of meeting most any nitrogen limit imposed by Federal and State regulatory agencies during summer months. A significant increase in effluent nitrogen occurred during the Labor Day weekend. It is not known why this occurred but it is believed that the student population attending Sunderland Elementary School and – perhaps more significantly – the students who seasonally reside in the Sunderland sewer service area and attend the University of Massachusetts create an increased loading on the wastewater treatment plant which results in a loss of nitrogen removal efficiency. Additional monitoring over a longer period of time is required to confirm cause and effect.

Throughout the study period plant staff operated the treatment plant at a sufficiently high mixed liquor concentration (3500 mg/L), hydraulic retention time (24+ hours), and ORP (100+ mV) to support ammonia removal. The dissolved oxygen concentration (DO) however was at times very low (less than 0.5 mg/L). Equipment limitations – specifically the amperage limit of the variable frequency drive controlling mechanical aeration – restrict staff's ability to supply all of the oxygen otherwise available.

Phosphorus Removal. No effort was made to implement biological phosphorus removal. However, the facility is well equipped to do so. A protocol for a full-scale trial is described in the section that follows.

Recommendations

General. Continue collecting, monitoring and recording in-house data. Continue monitoring ORP. Continue monitoring pH and alkalinity. Continue to increase plant knowledge and optimization skills by observing treatment processes and informally correlating ORP, DO, alkalinity and nitrogen data. Supplement in-house knowledge by continuing to actively search for resource materials.

Nitrogen Removal. Focus on optimizing ammonia removal first and nitrogen removal second by ensuring sufficient oxygen in the aeration tank during the air on cycles. Consider replacing the aerator VFD to one with a higher amperage capacity; one more suitable for the on-off cycling necessary for optimal nitrogen removal. Maintain high mixed liquor concentration so that sufficient nitrifying bacteria are available for (a) ammonia removal and (b) a DO/ORP drop during the air off cycle sufficient to support nitrate removal.

Phosphorus Removal. A decision was made to focus exclusively on nitrogen removal at the on-set of the optimization effort. Biological phosphorus removal however can be achieved by recycling sludge from the sludge holding tank to the aeration tank.

The time to experiment with biological phosphorus removal would be next summer after the plant is effectively removing ammonia to 1.0 mg/L or less. To begin the experiment ten percent of the waste sludge should be returned to the aeration tank daily; doing so keeps the bio-P bacteria in circulation. A corresponding increase in sludge wasting needs to occur to maintain the desired mixed liquor concentration. For further information on biological phosphorus removal, please refer to the attached, supplemental page.

Conclusions

There are two barriers to the Sunderland wastewater treatment plant achieving year-around nitrogen removal.

The first impediment is the effects felt immediately following Labor Day, presumably an annual event. A better understanding of what occurred is needed. Presumably, there is an annual increase in flow and loading; an increase that temporarily overwhelms the facility's ability to biologically remove nitrogen. The cause needs to be better understood (i.e., influent BOD, total-N, and flow – before and after Labor Day). After which, an action plan can be developed.

The second impediment is that of aeration equipment. It appears that, at times, operating at 88% the existing mechanical aerator is not capable of providing sufficient oxygen to support complete ammonia removal. Replacing the existing VFD with one that will allow the aerator to cycle on at 100% without tripping out may be sufficient.

*Note: The data are all in-house testing using non-EPA approved procedures. The total-N values are estimated by totaling ammonia, nitrite and nitrate and adding an assumed 2.0 mg/L organic-nitrogen value.

Enhanced Biological Phosphorus Removal

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Phosphorus is an essential nutrient in the growth of all living things. During conventional wastewater treatment, some 2 mg/L of phosphorus is typically removed from the wastestream and converted to bacterial mass. By weight, bacteria are approximately 1.5 percent phosphorus. Meaning, for every dry ton of waste sludge, 30 pounds of phosphorus is biologically removed from wastewater.

"Enhanced" biological phosphorus removal increases the dry weight component of phosphorus to as high as five percent, maybe more. Wastewater professionals who understand the process can quadruple phosphorus removal without the use of chemicals.

Enhanced biological phosphorus removal is a two step process: a period of anaerobic treatment (zero oxygen), followed by highly aerobic treatment at neutral or higher pH. Volatile fatty acids (VFAs) drive the process. VFAs are produced in anaerobic conditions.

The anaerobic treatment cannot be a digester; VFAs are destroyed during anaerobic digestion, they are converted to methane gas. In fact, the undesirable "acid" in the acid/alkalinity ratio that is used to monitor the effectiveness of anaerobic digesters is VFA. For enhanced biological phosphorus removal, it is important to ferment and not completely digest waste so that (i) a supply of volatile fatty acids are created in advance of an aerobic zone and (ii) a family of bacteria called PAOs, phosphate-accumulating organisms, take in the VFAs. The wastewater needs to contain approximately 25 times as much BOD as phosphorus in order to support biological phosphorus removal. During fermentation, the bacteria (PAOs) temporarily release a lot of the phosphorus stored within their cells into the wastestream.

When the PAO bacteria enter an aeration tank with high a high dissolved oxygen content and neutral pH (both conditions are very important for biological phosphorus removal) they use the VFAs as an energy source and take in all but 0.05 mg/L (or less) of the soluble ortho-phosphorus. The phosphorus is removed with the bacteria as waste sludge. There is a temporary increase in phosphorus concentration in anaerobic tanks.

Municipal wastewater treatment plant staff can create volatile fatty acids in any number of ways. VFAs can also be imported; for example with septage.

The three textbook ways of creating VFAs are: (i) in a mainstream anaerobic tank located ahead of aeration, (ii) in a primary sludge fermenter, and (iii) in a return sludge selector. Once established, the biological process needs little to no attention. Simply allow moderate to high BOD to remain anaerobic for a period of an hour or longer. Aerobic digesters can be converted to fermenters by turning the air off. Similarly, sludge holding tanks, gravity thickeners, and other zones of zero oxygen and high-BOD can be made into fermenters.

A well operating biological phosphorus removing facility can reduce effluent phosphorus to 0.2 mg/L. To achieve this level of treatment, the effluent TSS (total suspended solids) concentration must be very low. Each mg/L of effluent TSS contains approximately 0.05 mg/L of phosphorus. To meet an effluent limit of 0.5 mg/L or less, effluent TSS and effluent ortho-P must be closely monitored and controlled.